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An Annotated List of Selected References on Age and Growth Studies of Bluefin Tuna, Thunnus spp.

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CONTENTS

ABSTRACT

Annotations are presented for 74 selected papers published since 1928 on age and growth determination of two primary species, Thunnus thynnus and Thunnus maccoyii-, and two subspecies, T. thynnus thynnus and T. thynnus orientalis, of bluefin tuna. A subject index is included for each designation.

INTRODUCTION

This list of references consists of 74 papers which address the general topic of estimating age and growth rate of bluefin tuna, Thunnus spp. The literature indicates that bluefin tuna occur as two primary species, Thunnus thynnus and Thunnus maccoyii, and 'as two subspecies, Thunnus thynnus orientalis and Thunnus thynnus thynnus.. One primary species Thunnus thynnus found in the Atlantic between 20°s latitude and 70°N latitude, as well as in the Mediterranean and Black Seas (Tiews 1963; Mather and Jones 1972; Mather et al. 1973; Sakakawa and Coan 1973; Parrack 1979) and is occasionally referred to with the subspecies designation of Thunnus thynnus thynnus. The other subspecies, Pacific bluefin tuna, Thunnus thynnus orientalis, is found in the Pacific Ocean between 35°s latitude and 60°N latitude (Koski 1967; Schultz and Collins 1977; Bayliff 1980) and is often designated in the literature as either Thunnus orientalis or Thunnus'thynnus (Pacific Ocean). Southern bluefin tuna, Thunnus maccoyii, the Other primary species, occurs only in the southern hemisphere in the Pacific and Indian Oceans between 50°s to 0° latitude and 20°E to 8O°W longitude, and in the Atlantic Ocean between 20°s to 50°s latitude (De Jaeger 1963; Robins 1963; Murphy 1977; Murphy and Majkowski 1981; Olson 1981).

Over-exploitation of the bluefin tuna stocks, particulary in the Atlantic Ocean, has been a growing concern of many nations (Lee et al. In press; Caddy and Butler 1976). Biological studies of age and growth are an integral part of stock assessment and a critically important component in the data base used for formulating management regulations. The last comprehensive review of the literature on age and growth of bluefin tuna was by Bell (1962). Recent studies have reported new methodologies for preparing and examining skeletal hardparts and enhancing associated growth bands. Estimates of age using these techniques have resulted in increases in estimated longevity of this species. In order to update the present work in this area, we selected references if the subject provided age and growth estimates based on analyses of skeletal hardparts, tag and recapture data, or size frequencies. Inferences to age or age composition of catch based on previously published studies or von Bertalanffy parameters were also included. Initially, the literature was examined for references pertaining to western Atlantic bluefin tuna, but was expanded to include the eastern Atlantic population, as well as the Pacific and southern bluefin tuna. Numerous references published in languages otherthan English and not containing English summaries or abstracts, could not be translated within the restrictions of this effort and are not included here.

"References are listed alphabetically by the first author's surnane. Each entry is annotated to provide a subject overview and facilitate location of a reference covering a specific area of interest.<:.-

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AIKAWA, H., and M. KATO.
1938. Age determination of fishes (preliminary report 1) Bull. Jap. Sco. Sci. Fish. 7(1):79-88 (Transl. by W.G. Van Campen, U.S. Fish and Wildl. Serv., Spec. Sci. Rep. Fish. (1950) 21: 22 p.

Estimations of age and growth rate determined for eastern Pacific bluefin tuna, Thunnus orientalis, and other scombrids, Neothunnus macropterus, Germo permo, and Katsuwonus vagans based on ring counts of anterior vertebrae from fish caught during 1936-1938. Estimated ages of 1-9 years determined for 21 specimens of T. orientalis ranging in size 34-211 cm (fork length). Methodology for vertebra analysis described. Length and weight ranges for ages 1-9 years presented for T. orientalis. Regression correlation of vertebra radius to body Length also examined.

Key words: Thunnus orientalis, eastern Pacific bluefin tuna, vertebrae, methodology , age estimates.

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BAGLIN, R.E., JR.
1978. Length and age composition per set of bluefin tuna (Thunnus thynnus) from the United States northwest Atlantic purse seine vessels. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 7(2): 349-351.

Fish tagging operations described for Atlantic bluefin tuna, Thunnus thynnus, aboard United States purse seine vessels. Length measurements from 5,601 school bluefin tuna collected during the 1974, 1976, and 1977 tagging seasons assigned estimated ages of 1-4 years based on length-age relationships determined in other published studies. Percentage of age composition of the catches and the degree of heterogeneity of schools discussed.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, age composition, heterogeneity.

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BARD, F.X., J.L. CORT, and J.C. REY.
1973. Commentaires sur la composition demographique des peches de thon rouge (Thunnus thynnus) de l'est Atlantique et de la Mediterranee, 1960-19-n Fr., Enq. summ.) Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 7(2):355-365.

Partially translated study on age and growth determination conducted on eastern Atlantic bluefin tuna, Thunnus thynnus, caught in the eastern Atlantic Ocean and Mediterranean Sea. Estimates of age for 1-3 year olds derived from length frequency modes. Large tuna-older than 3 years assigned apes based on results of a previously published study. Von Bertalanffy growth parameters calculated and length-weight-age table presented by month (June-November) for estimated ages 0-23 years. Summary of ape composition of tuna catches by various countries for the period 1951-1977 given.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, von Rertalanffy growth parameters.

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BAYLIFF, W.H.
1980. Synopsis of biological data on the northern bluefin tuna, Thunnus thynnus (Linnaeus, 1758), in the Pacific Ocean. In W.H. Bayliff (editor), Synopsis of biological data on eight species of scombrids. p. 261-294. Inter-Am. Trop. Tuna Comm., Spec. Rep. No. 2.

Species distribution, life history parameters, population structure, exploitation, and management regulations summarized from previously published studies on north Pacific bluefin tuna, Thunnus thynnus orientalis. Review of age and growth studies-indicated ages of 6-10 years based on analyses of scales and vertebrae. Estimates of von Bertalanffy growth parametes calculated.

Key words: Thunnus orientalis, north Pacific bluefin tuna, age estimates, von Bertalanffy growth parameters, scales, vertebrae.

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RAYLIFF, W.H., and T.P. CALKINS.
1979. Information pertinent to stock assessment of northern bluefin tuna, Thunnus thynnus, in the Pacific Ocean. Inter-Am. Troo. Tuna Comm. Internal Rept. No. 12: 75 p.

Length frequency analysis presented for estimation of age class based on 42,817 northern Pacific bluefin tuna, Thunnus thynnus, caught during 1952-1978 by various surface fisheries. Modes larger than 70 cm (fork length) were found difficult to interpret. Von Bertalanffy growth parameters determined based on tag recovery data from 105 fish. Resulting growth rate for estimated apes 1-6 years compared to growth rates from other published studies in which estimated ages were determined from scale analyses. Migration, mortality rates, catch and effort statistics, and historical account of surface fisheries also discussed.

Key words: Thunnus thynnus, north Pacific bluefin tuna, length frequency, tagging data, scales, von Bertalanffy growth parameters.

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BELL, R.R.
1962. P. history of tuna ape determination. In Proc. Scombroid Fishes, Part II: 693-706. Mar. Biol. Assoc. India, Diocesan Press, India.

Reviews literature through 1961 concerning age determination of Atlantic bluefin tuna, Thynnus thynnus, Pacific bluefin tuna, T. orientalis, and other scombridsmes of skeletal hardparts-used in the various studies showing sample size. area caught, size and age ranges for each species given. Maximum estimated age of 18 years reported for T. thynnus and 9 years for T. orientalis.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Thunnus orientalis, Pacific bluefina, vertehrae, scales, length frequency.

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BELL, R.R.
1963. Preliminary age determination of bluefin tuna, Thunnus thynnus. Calif. Fish and Game 49(l): 307.

Estimation of age determined for north Pacific bluefin tuna, Thunnus thynnus, caught in California waters during 1961-1962 based on analysis of scales taken from the caudal peduncle. Methodology for staining given. Scales from 247 specimens ranging 51-142 cm (fork length) gave estimated ages of 0-5 years. Mean length and length ranges given for each age.

Key words: Thunnus thynnus, north Pacific bluefin tuna, scales, staining methodology.

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BERRY, F.H., D.W. LEF, and A.R. BERTOLINO.
1977. Age estimates in Atlantic bluefin tuna -- an objective examination and an intuitive analysis of rythmic markings on vertebrae and in otoliths. (Title revised to: Progress in Atlantic bluefin tuna ageing attempts). Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 6(2): 305-317.

An analysis of western Atlantic bluefin tuna, Thunnus thynnus, caudal vertebrae and otoliths (sagittae) for age determination. Provides description of skeletal hardparts examined as -well as techniques for processing and storage. Methodology of vertebra staining and otolith cross sectioning for enhancing growth increments described. Interpretation of growth increments and its implication to age determination discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, otolith (sagitta), vertebra, methodology.

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BROTHERS, E.B., E.D. PRINCE, and D.W. LEE.
In press. Age and growth of young-of-the-year bluefin tuna (Thunnus thynnus) from otolith microstructure. In E.D. Prince and L.M. Pulos (editors), Proceedings of the international workshop on ape determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS.

Growth band microstructure in otoliths (sagittae and lapilli) from 350 larval and 44 juvenile Atlantic bluefin tuna, Thunnus thynnus, analyzed for growth rate, estimation of ape, and spawning time. Fish sampling procedure and methodology of otolith analysis described. Otolith microstructure appeared to represent daily growth units and could be used for age determination. Growth rates indicated substantial

variation in larval growth and correlated with ability to survive to juvenile stages.

Key words: Thunnus thynnus, Atlantic bluefin tuna, otoliths, daily growth increments.

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BUTLER, M.J.A.
1971. Biological investigations on aspects of the life history of bluefin tuna, 1970-71. Newfoundland and Labrador Tourist Development Office (Contr. No. 162, Dept. of Bio., Memorial Univ., St. John's, NFLD.) 196 p.

Detailed life history investigation conducted on giant western Atlantic bluefin tuna, Thunnus thynnus. Provides results of age and growth estimates for bluefin tuna caught during 1965-66 in coastal waters off Newfoundland based on rinq counts of anterior vertebrae. Methodology for vertebra processing and staining described. Estimated apes of 10-14 years determined for 41 bluefin tuna ranging 218-257 cm (fork length) and these results compared to other bluefin tuna age and growth studies. Growth parameters derived from Walford plot given and length-weight-age curves developed. Tuna taxonomy, stock distribution, migration, reproduction, spawning areas, feeding behavior and other life history information discussed.

Key words: Thunnus thynnus, giant western Atlantic bluefin tuna, vertebrae, methodology.

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BUTLER, M.J.A.
1974. Prince Edward Island bluefin tuna research program, 1974. 165 p. Unpubl. manuscr. St. Andrews Biological Station, N.B., Can.

Report of scientific investigations conducted on giant Atlantic bluefin tuna, Thunnus thynnus, caught during 1973-74 in coastal waters of Prince Edward Island, Canada. Age and growth determination based on growth band analysis of caudal vertebrae and otoliths (sagittae). Methodology for preparing and analyzing the skeletal hardparts described. Vertebra analysis of 61 specimens ranging from 158-287 cm (fork length) pave estimated ages of 9-22 years. Thin cross-sections of 29 sagittae indicated estimated ages of 17-25 years. Length-weight-age table provided. Discusses ultrasonic tagging, food and feeding behavior, sex ratio, and effects of oceanographic and meterological conditions on catches.

Key words: Thunnus thynnus, qiant western Atlantic bluefin tuna, vertebra, otoliths, methodology.

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BUTLER, M.J.A.
1982. Plight of the bluefin tuna. Nat. Geogr. 162(2):220-239.

Article describes scientific research, exploitation and resource utilization of the Atlantic bluefin tuna, Thunnus thynnus. Physiology, behavior, and historical profiles of the species also discussed. References to size and estimated ages given, including a maximum age estimation of 35 years.

Key words: Thunnus thynnus, Atlantic bluefin tuna, ape estimates.

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BUTLER, M.J.A., J.F. CADDY, C.A. DICKSON, J.J. HUNT, and C.D. BURNETT.
1977. Apparent age and growth based on otolith analysis of giant bluefin tuna (Thunnus thynnus thynnus) in the 1975-76 Canadian catch. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 6(2):318-330.

Estimations of age and growth determined for giant western Atlantic bluefin tuna, Thunnus thynnus, caught in Canadian waters during 1975-76 based on growth band analysis of otolith (sagitta) cross-sections. A technique for otolith extraction and methodology for cross sectioning described. Examination and criteria for growth band interpretation discussed. Estimated ages based on otolith analysis of 189 specimens ranged 11-26 years. Von Bertalanffy growth parameters determined for each sex and growth curves fitted to length-age data. Growth rate briefly mentioned.

Key words: Thunnus thynnus, giant western Atlantic bluefin tuna, methodology, otolith, von Bertalanffy growth parameters.

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CADDY, J.F.
1974. Cohort analysis of Atlantic bluefin tuna and estimates of escapement through the juvenile fisheries under two hypotheses of catch age structure. Inter. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 43186-197.

Cohort analyses on pooled estimates of surface fishery catches of Atlantic bluefin tuna, Thunnus thynnus, presented and discussed. Estimated ages of 1-14+ years assigned to catches based on previously published age estimates. Tables indicating number of fish at each age for Atlantic-wide catches from 1957 to 1971 presented. Recent evidence indicated that band counts from vertebrae and otoliths (sagittae) showed good agreement and suggested older age estimates for giant bluefin tuna (16-22 years) than previously reported. Calculations of recruitment and mortality rates at specific ages also discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age estimates, vertebra, otoliths.

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CADDY, J.F., and M.J.A. BUTLER.
1976. Recent catch trends and age composition in Canadian coastal fisheries for giant bluefin tuna (Thunnus thynnus) and their relevance

to assessment of the northwest Atlantic large fish stocks. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 5(2):244-257.

Examines recent fishing exploitation, size data, and age composition of catch of giant Atlantic bluefin tuna, Thunnus thynnus, from five Canadian coastal fisheries. Methodology for cross-sectioning bluefin tuna otoliths (sagittae) briefly described. Comparison of age estimates between vertebra and sectioned otoliths gave close agreement up to 16 years, after which otolith suggested older age estimates. Estimated ages of 11-30 years determined from otolith sections. Age structure between eastern and western Atlantic compared and discussed. Catch rates under alternative fishing strategies and comparison of catch trends of giant tuna in eastern and western Atlantic also discussed.

Key words: Thunnus thynnus, giant western Atlantic bluefin tuna, vertebra, otoliths, hardpart methodology, age estimates.

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COAN, A.L.
1976. Length, weight, and age conversion tables for Atlantic tunas. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 5(1):64-66.

Age, length, and weight conversion tables presented for bluefin tuna, Thunnus thynnus, and other tunas, Katsuwonus pelamis, Thunnus alalunga, and Thunnus albacares. Von Bertalanffy growth parmeters obtained from previously published studies are presented for each species. Table of fork length, round weight, and estimated ages (0.17-19+ years) calculated for bluefin tuna. Other species similarly described.

Key words: Thunnus thynnus, Atlantic bluefin tuna, von Bertalanffy growth parameters.

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COPPELN-JIMENEZ, G., and F.X. BARD.
1980. Age and growth of each Atlantic bluefin tuna, Thunnus thynnus, as determined by reading of fin ray cross section. [In Fr., Ena. summ.] Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 9(2):547-552.

Partial translation of ape and growth estimations conducted on eastern Atlantic bluefin tuna, Thunnus thynnus, based on cross section analysis of the first dorsal spine. Methodoloqy for sectioning spines described. Cross-sections from 144 specimens ranging 60 to 278 cm (fork length) examined and estimated ages of 1-19 years assigned based on assumption of forming two rings per year. Physiological factors contributing to growth band formation discussed. Von Bertalanffy growth parameters and mean length-at-age relation determined.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, dorsal spines analysis, sectioning methodology, von Bertalanffy parameters.

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COMPEAN-JIMENEZ G. and F.X. BARD.
In press. Growth increnents on dorsal spines of eastern Atlantic bluefin tuna, Thunnus thynnus, and their possible relation to migration patterns. In E.D. Prince and L.M. Pulos (editors), Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS.

Estimation of age and growth of eastern Atlantic bluefin tuna, Thunnus thynnus, determined based on dorsal spine cross-sections. Methodology for sectioning dorsal spines described. Estimated ages of 1-19 years determined from analysis of 227 sectioned spines from tuna 40 to 278 cm (fork length). Von Bertalanffy growth parameters calculated and table of mean length at estimated age presented. Formation of two paired bands per year proposed and discussed.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, methodology, dorsal spine, von Bertalanffy growth parameters.

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CORSON, R.H.
1923. Fire Island fish notes. Copeia 1923 (123):108.

Two Atlantic bluefin tuna, Thunnus thynnus, caught off Fire Island, New York, estimated to be 2 and 5 years old based on scales taken from posterior portion of the body.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, scales.

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De JAEGER. B.
1963. Synopsi s of biological data on bluefin tuna Thunnus thynnus orientalis (Temminck and Schlegel) 1842, longfin tuna, Thunnus alalunga (Bonnaterra) 1788, yellowfin tuna, Thunnus albacares (Bonnaterrm and bigeye t una, Thunnus obesus (Lowe) 1839 (South Africa). FAO Fish. Biol. Synop.

Summary report of data collected during 1960-61 on bluefin tuna, Thunnus thynnus orientalis, and 3 other scombrids, T. alalunga, T. albacares, and T. obesus caught in the Atlantic coastal waters of the Republic of South Africa. Distribution. annual occurrence. and life history information discussed. Age of largest bluefin tuna collected estimated at 8 years old based on previously published ageing study results.

Key words: Thunnus orientalis,' southern Atlantic bluefin tuna, age determination.

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FARBER, M.I., and D.W. LEE
1981. Ageing western Atlantic bluefin tuna, Thunnus thynnus, using tagging data, caudal vertebrae and otoliths. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 15(2):536-546.

Estimation of age and growth determined for western Atlantic bluefin tuna, Thunnus thynnus, caught during the period 1966-1978 based on analyses of caudal vertebrae, otoliths (sagittae) and growth rate derived from tag recaptured data. Methodology for preparing, staining, and clearing skeletal hardparts described. Estimated ages based on 1061 vertebrae and 123 otoliths ranged from O-14 years and O-8 years, respectively. Von Bertalanffy growth parameters derived from tagging and vertebra data fell within the range of growth parameters reported previously by other studies on bluefin tuna. Relationship of vertebrae cone radius and otolith radius determined by regression analysis, as well as back-calculated fork lengths presented.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, tag recapture, vertebra,otolith, von Bertalanffy growth parameters.

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FARRUGIO, H.
1977. Donnes preliminaires sur la peche au thon rouge au filet tournant en Mediterranee Francaise. [In Fr., Engl. Summ.] Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 6(2):245-251.

Describes age composition of catch of Atlantic bluefin tuna, Thunnus thynnus, landed during 1966-1975 by the French purse seine fishery operating in Mediterranean waters. Length-weight-age table derived from a previously published study presented for estimated ages 1-10 years.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Mediterranean Sea, age composition.

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FARRUGIO, H.
1978. Estimation de la composition demographique de la pecherie de surface on thon rouge en Mediterranee Francaise de 1969 a 1976. [In Fr., Eng. Summ.]. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pan., Madrid 7(2):352-354.

Compares length-weight-age results from previously published age and growth studies on eastern Atlantic bluefin tuna, Thunnus thynnus. Von Bertalanffy growth parameters calculated and presented as table of length-weight-age for each quarter year from O-12+ years. Age composition of Mediterranean French fisheries for 1969-1976 presented and discussed.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, Mediterranean Sea, von Rertalanffy growth parameters, age composition.

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FARRUGIO, H,
1979a. Resultant de la compagne de peche on thon rouge en Mediterranee Francaise en 1977; premieres observations pour 1978. [In Fr., Eng. Summ.]. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap. , Madrid 8(2):313-314.

Describes the age composition of the French catch of Atlantic bluefin tuna, Thunnus thynnus, from Mediterranean waters in 1977. Age estimates derived from previously published age and growth study. Total catch presented by age class (monthly), percent of catch, and total catch by age for ages 1-10+ years.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Mediterranean catches, ape composition.

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FARRUGIO, H.
1979b. Revue comparative des etudes sur la croissance du thon rouge Thunnus thynnus (Linne, 1758). [In Fr., Eng. Summ.]. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 8(2):343-355.

Comparison of previously published von Bertalanffy growth parameters for Atlantic bluefin tuna, Thunnus thynnus, were discussed. Tables of length and weight ranges calculated for each age given for estimated ages 1-20 years. Presents a general length-weight-age key for eastern Atlantic and Mediterranean bluefin tuna without overlapping values for ages 1-10 years.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Eastern Atlantic and Mediterranean, von Bertalanffy growth parameters.

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FARRUGIO, H.
1980. Age et croissance du thon rouge (Thunnus thynnus) dans la pecherie Francaise de surface en Mediterranee. [In Fr., Engl. summ.]. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap:, Madrid 9(2):536-546.

Age and growth estimates determined based on length frequency modes and caudal vertebra ring counts of Mediterranean caught Atlantic bluefin tuna, Thunnus thynnus, during the period 1975-1977. Petersen method applied to weight data of tuna 3 to 50 kg resulting in estimated ages of 1-5 years. Methodology for enhancing vertebra growth rings described. Estimated ages based on the 36th vertebra ring counts ranged from 1-9 years. Von Bertalanffy growth parameters calculated from length frequency and vertebra data and the resulting growth models compared to other studies. Estimated lengths at age from back calculations of ring measurements and regression analysis of cone radius given as well as discussion on growth rate and length-weight results.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Mediterranean Sea, length frequency, vertebra, von Bertalanffy growth parameters.

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FURESTIN, J., and J. DARDIGNAC.
1962. Le thon rouge due Maroc Atlantique (Thunnus thynnus Linne). Rev. Trav. Inst. Peches marit. 26(4):381-398.

Examines linear growth of eastern Atlantic bluefin tuna, Thunnus thynnus, using morphometric data collected during 1949-1954 in Atlantic coastal waters of Morocco. Estimated ages and rate of growth determined from 6 months to 2 l/2 years based on length frequency analyses and compared to previously published ageing studies.

Key words: Thunnus thynnus, Atlantic bluefin tuna, length frequency, age estimates.

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HAMRE, J.
1958. About the age composition of Norwegian tuna catches in the years 1954-1958. Int. Coun. Explor. Sea. (91): 12 p.

Age and growth study conducted on Atlantic bluefin tuna, Thunnus thynnus, caught in Norwegian waters based on ring counts of vertebrae collected during 1955-1956. Estimated ages of 5-13 years determined from 322 vertebrae examined. Mean length-weight-ape table given and resulting growth curves compared to an earlier published study conducted on Mediterranean bluefin tuna. Migration, age composition and variation in tuna catches during 1954-58 also discussed.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, North Sea, vertebrae, staining technique.

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HAYASHI, S.
1957. A review of age determination of the Pacific tunas. Indo-Pacific Fish. Counc. 7(2-3):53-64.

Review of age and growth studies conducted on Pacific bluefin tuna, Thunnus thynnus, and 4 other tuna species, T. alalunga, Parathunnus obesus, Neothunnus albacares, and Katsuwonus pelamis. Studies reviewed used analyses of length-weight frequency modes, vertebrae. and scales to determine age. Growth curves from three Pacific bluefin tuna studies compared to two Atlantic bluefin tuna studies. Other species similarly described.

Key words: Thunnus thynnus, Pacific bluefin tuna, scales, vertebrae, length frequency, growth curves.

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HUNT, J.J., (editor).
1978. Proceedings of the Atlantic bluefin ageing workshop. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 7(2):332-348.

Report of research by workshop participants involved in age determination of Atlantic bluefin tuna, Thunnus thynnus. Detailed description of methodology for collecting and storing otoliths and vertebrae, as well as techniques for enhancing growth increments described. Indirect ageing methods using tag recapture data, chemical tags, and length frequency modes discussed. Von Bertalanffy growth parameters derived using combined results from two studies previously published. Recommendations for continued,research studies proposed,

Key words: Thunnus thynnus, Atlantic bluefin tuna, otoliths analysis, vertebra analysis, von Bertalanffy growth parameters, hardpart methodology.

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HURLEY, P.C.F., and T.D. ILES.
1982a. An unusual bluefin tuna tag return. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 17(2):295-298.

Report of tagged Atlantic bluefin tuna, Thunnus thynnus, recaptured in 1981 which had been at large for almost 16 years. Release data estimated the tuna to be a 2 year old based on size at tagging, thereby establishing age of this bluefin tuna to be 18+ years old. Estimated ages of 11.9-21.1 years were obtained when estimated forklength of the recaptured specimen was fitted to previously published von Bertalanffy growth equations. The 36th caudal vertebrae was obtained from this fish and age validation studies using this structure were conducted by the National Marine Fisheries Service, Miami, Florida.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, tagged recapture data, von Bertalanffy growth par-meters.

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HURLEY, P.C.F., and T.D. ILES.
1982h. Changes in the bluefin tuna stock in the Gulf of St. Lawrence in 1980 and their implications. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 17(2):299-306.

Estimated age composition of Atlantic bluefin tuna, Thunnus thynnus, caught in Canadian waters during 1975-1979 ranged 5 to 30 years based on analysis of 1,137 otolith cross sections. Predominate age groups of giant bluefin tuna composed of 16-26 year olds. Canadian bluefin fisheries described and management regulations summarized. Catch-per-unit-effort (CPUF) and virtual population analysis (VPA) calculated and results discussed.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, age estimates.

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HURLEY, P.C.F., and T.D. ILES.
In press. Age and growth estimations of Atlantic bluefin tuna, Thunnus thynnus thynnus, using otoliths. In E.D. Prince and L.M. Pulos (editors) of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS.

Estimation of ape and growth determined for western Atlantic bluefin tuna, Thunnus thynnus, caught along the Canadian and United States coastline during 1975-1981 based on analysis of otolith (sagitta) cross sections. Methodology for collecting and sectioning otoliths for analysis described. Estimated ages of 1-32 years determined from 1,416 otoliths examined. Von Bertalanffy growth parameters calculated for each sex and table of mean length at age presented for males and females.

Key words: Thunnus thvnnus. western Atlantic bluefin tuna, otolith, von Bertalanffy growth parameters, age estimates.

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HURLEY, P.C.F., T.D. ILES, and C.A. DICKSON.
1981. Age and growth of bluefin tuna taken in Canadian waters in recent years. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 15(2):284-287.

Estimates of aqe and arowth determined for western Atlantic bluefin tuna, Thunnus thynnus, caught in Canadian waters during 1975-1979 based on the analysis of internal growth increments from otolith (sagitta) cross sections. Estimated ages of 11-30 years determined for 1095 otoliths examined. Von Bertalanffy growth parameters calculated for each sex and compared to parameters derived from other growth studies on Atlantic bluefin tuna.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, Canadian waters, von Bertalanffy parameters, otolith analysis.

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ISAACSON, P.A.
1964. Ape composition of the commercial California bluefin tuna catch in 1963. Comm. Fish. Rev. 26(11):12-14.

Estimates of age determined for Pacific bluefin tuna, Thunnus thynnus, landed at Terminal Island, California during 1963 based on scale and length frequency analyses. Scales from 1,038 specimens ranging in fork length from 56 to 173 cm examined and estimated ages of O-6 years determined. Length frequency modes compared to mean length at age data determined from scale analysis. Age composition of 1963 California landings described.

Key words: Thunnus thynnus, Pacific bluefin tuna, scales, length frequency.

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KIMURA, K.
1932. Growth curves of bluefin tuna and yellowfin tuna based on the catches near Sigedera, on the west coast of Prov. Izu. [In Jap., Eng. syn.] Bull. Jap. Soc. Sci. Fish. 1(1):1-4. (Available in U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 22(1950):11-16.)

Age and growth estimations determined for Pacific bluefin tuna, Thunnus orientalis, and yellowfin tuna, Neothunnus macropterus, caught in the coastal waters of Japan based on weight frequency distribution of an unspecified number of fish. Growth curves representing estimated ages of 1-5 years determined for bluefin tuna and 1-6 years for yellowfin tuna. Presence of large bluefin tuna older than six years mentioned, but growth rate not analyzed.

Key words: Thunnus orientalis, Pacific bluefin tuna, weight frequency, age estimates.

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KOSKI, R.T.
1967. Age and growth determinations of bluefin tuna in the north Pacific Ocean. M.S. Thesis, Calif. State College, Long Beach, Calif. 51 p.

Age and growth investigation conducted on Pacific bluefin tuna, Thunnus thynnus orientalis, caught in coastal waters of southern California and Baja California during 1963-65 based on analyses of scales, length frequency modes, and tag recapture data. Technique for collecting scales described and methodology of staining given. Estimated ages of 1-6 years determined from examination of 3,260 specimens. Validation of growth marks analyzed by comparing results of scales aped from recaptured fish of known age and length frequency modes. Mean back-calculated length at age and von Bertalanffy growth parameters presented. Criteria for determining annuli on scales, time of annulus formation and growth rates discussed.

Key words: Thunnus orientalis, Pacific bluefin tuna, scale analysis, tag recapture data, length frequency, von Bertalanffy parameters, growth rate, age validation.

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LEE, D.W., E.D. PRINCE, and M.E. CROW.
In press. Interpretation of growth bands on vertebrae and otoliths of Atlantic bluefin tuna, Thunnus thynnus. In E.D. Prince and L.M. Pulos (editors), Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS.

Vertebrae and otoliths (sagittae) of 2,287 western Atlantic bluefin tuna, Thunnus thynnus, collected 1975-79 were examined and analyses of growth-and age validation discussed. Methodologies for staining vertebrae and cross sectioning otoliths described. The 36th vertebra obtained from a tag-recaptured giant bluefin tuna where an age of 18 years was known based on tagging records, suggested each growth band on

this vertebra represented at least 1 year of life. Analysis of the terminal translucent zone measurements on otolith cross sections from 554 giant tuna (>209 cm, FL) suggested the formation of two bands per year on otoliths after age of maturity. Growth band counts of the 35th and 36th vertebra and of two different interpretations of counts on otolith cross sections from the same fish compared and discussed.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, otoliths, vertebrae, methodology, age validation.

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LE GALL, J.
1954. Thon rouge, Thunnus thynnus (Linne). Rev. Trav. Inst. Peches Marit. 18(2-4):65-67.

Brief summary of migration and distribution patterns of the Mediterranean population of the Atlantic bluefin tuna Thunnus thynnus. Length and weight ranges for young-of-the-year (estimated ages of 4 and 8 months) and estimated ages of 1-12 years presented based on previously published data. Maximum age estimated at 15 years. Indication of growth of Mediterranean caught tuna to be similar to growth of tuna found in coastal waters of Europe and North America.

Key words: Thunnus thynnus, Atlantic bluefin tuna, Mediterranean Sea, aqe and growth estimates.

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LUCAS, C.
1974. Working paper on sothern bluefin tuna population dynamics. Int. Corn-n. Conserv. Atl. Tunas, Coil. Vol. Sci. Pap., Madrid 3:111-124.

Effects of Australian and Japanese commercial fishing exploitation on Pacific southern bluefin tuna, Thunnus maccoyii, population examined. Von Bertalanffy growth parameters derived from tagging data of 116 recaptured fish and growth curve presented for estimated ages 1-12 years. Growth model of tagging data compared to growth model determined by scale analysis from previously published study and results discussed. Tagging experiment described and rates of tag shedding and mortality estimates calculated.

Key words: Thunnus maccoyii, southern bluefin tuna, tag analysis, estimated ages, von Bertalanffy growth parameters.

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MAJKOWSKI, J., and J. HAMPTON.
In Press. Deterministic partitioning of the catch of southern bluefin tuna, Thunnus maccoyii, into age-classes using an age-length relationship. In E.D. Prince and L.M. Pulos (editors), Proceedings of the international workshop on age determination of oceanic pelagic fishes: tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS.

Presents method for partitioning annual catch data of southern bluefin tuna, Thunnus maccoyii, collected from Australian and Japanese surface fisheries into ape classes based on age-length relationship. Von Bertalanffy growth parameters derived from unpublished tag-recapture and length frequencies presented and the equation of age-length relationship used as basis for partitioning the catch data in age classes. Potential errors in the partitioned catch estimates discussed and errors attributed to the parameters of the ape-length equation assessed using Monte-Carlo computer simulations. Age classes from 1-20 years presented.

Key words: Thunnus maccoyii, southern bluefin tuna, von Bertalanffy growth parameters, methodology, tag recapture, length frequency, age classes.

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MATHER, F.J., III.
1974. The bluefin tuna situation. In Proc. 16th Ann. Int. Game Fish Res. Con.: 93-120.

Addresses the growing concern over the declining abundance of the Atlantic bluefin tuna, Thunnus thynnus, stocks. Discusses tag return data, intensity and efficiency of the Atlantic surface fisheries, and stock structure imbalances. Table of estimated ages with mean length and weight presented for each age from 0-14 years derived from previously published studies. Suggested that growth of bluefin tuna is now more rapid than previously indicated because of over exploitation of the population.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age detemination.

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MATHER, F.J., III.
1980. Note on relationship between recently acquired mark recaptured data and existing age estimates for Atlantic bluefin tuna. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 9(2):470-477.

Three tap recaptured giant Atlantic bluefin tuna, Thunnus thynnus, at-large for 13.1-14.1 years resulted in documented ages of 15.3, 16.3 and 22+ 1 years old. Age, length, and weight of the three fish were compared to previously published growth relationships on Atlantic bluefin tuna determined from tag release-recapture data, length frequency analysis, and skeletal hardpart examination. Longevity of bluefin tuna exceeding 30 years and validity of calculated assymptotic length also discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, ageing, tag release-recapture data.

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MATHER, F.J., III, and A.C. JONES.
1972. A preliminary review of the stock structure of bluefin tuna in the Atlantic Ocean. 18 P. Unpubl. manuscript. Woods Hole Ocenographic Inst., Woods Hole, MA. 02542.

Summarizes previously published reports describing migration, distribution, reproduction and age structure of Atlantic bluefin tuna, Thunnus thynnus. Table of mean length and weight at each age derived from previously published growth studies presented for estimated apes 1-14 years. Summary of size frequency data of tuna catches for 1946-1970 given by pear and country.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age estimates.

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MATHER, F. J., III, and H.A. SCHUCK.
1960. Growth of bluefin tuna of the western north Atlantic. U.S. Fish Wildl. Serv., Fish. Bull. 61(179):39-52.

Estimates of age and growth determined for Atlantic bluefin tuna, Thunnus thynnus, caught in coastal waters of Cape Cod, Massachussetts, and Long Island, New York, based on the analyses of scales, caudal vertebrae, and length frequency data. Estimated ages of O-14 years determined for 197 specimens based on the composite use of scales from small tuna (<50 lbs) and vertebrae from larger fish. Length frequency analysis of 4,990 bluefin tuna correlated well with age groups O-5 years. Criteria for annulus interpretation described and growth rates discussed. A growth curve and tables of mean length and weight for each ape (O-14 years) presented.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, vertebrae, scales, length frequency.

* * *

MURPHY, G.I.
1977. New understanding of southern bluefin tuna. Aust. Fish. 36(l): 2-6.

An examination of yield per recruit estimates made for surface fisheries on southern bluefin tuna, Thunnus maccoyii, caught in Australian coastal waters and in the Tasman and Southern Oceans. Growth rate estimated from 2,578 tag recoveries used to calculate von Bertalanffy growth parameters. Catch yields at various ages and mortality coefficients calculated and discussed. Migration routes by age and recruitment stability discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, tagging data, von Bertalanffy growth parameters.

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MURPHY, G.I., and J. MAJKOWSKI.
1981. State of the southern bluefin tuna population: fully exploited. Aust. Fish. 40(11):20-29.

Evaluation of the exploitation by surface fisheries on southern bluefin tuna, Thunnus maccoyii, stocks presented. Estimates of von Bertalanffy growth parameters derived on the basis of tagging data and the growth curve presented for estimated ages 1-20 years. Proposed migration pattern and mortality estimates also determined from tagging study. Changes in the Japanese and Australian fisheries, recruitment and resource abundance discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, tagging study, von Bertalanffy growth parameters, age estimates.

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NICHY, F., and F.H. BERRY.
1976. Ape determination in Atlantic bluefin tuna. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 5(2):302-306.

Age determination of Atlantic bluefin tuna, Thunnus thynnus, investigated based on preliminary analysis of scales, vertebrae, and otoliths (sagittae). Selection of scale collection site and staining techniques described. Methodology for storing and preserving caudal vertebra and staining technique for growth zone enhancement described. A detailed description of otolith removal and storage, as well as methodology for cutting thin cross sections given. Internal characteristics of the growth zones in otolith cross sections described and estimated ages of up to 27 years proposed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, scales, vertebrae, otoliths, age estimates.

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OLSfiN, R.J.
1980. Synopsis of biological data on the southern bluefin tuna, Thunnus maccoyii (Castelnau, 1872). In W.H. Bayliff (editor), Synopsis of biological data on eight species of scombrids, p. 151-212. Inter-Am. Trop. Tuna Comm., Spec. Rep. No. 2.

Reviews published studies on southern bluefin tuna, Thunnus maccoyii. Estimates of age and growth rate provided based on length frequency, scales, and tagging data analyses. Table of von Bertalanffy growth parameters from the published studies given and length-at-age calculated for estimated ages of 1-10 years. Maximum age of 20 years proposed. Distribution, life history information, population structure, and exploitation discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, age estimates, von Bertalanffy growth parameters, scales, length frequency, tag-recapture data.

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PARRACK, M.L.
1979. An assessment of Atlantic bluefin tuna resources. In G.T. Sakagawa (chairman), Unit stock management of highly migratory species: Is it an imperative? p. 37-39. Proc. 30th Ann. Tuna Conf., Southwest Fisheries Center, La Jolla, CA 92038.

Briefly describes geographical distribution, spawning areas, migration, surface fisheries, and countries exploiting the Atlantic bluefin tuna, Thunnus thynnus. Proposed bluefin tuna live 20-30 years and reach a maximum size of up to 320 cm (fork length) and 700 Kg (round weight). Includes length-age curve based on analysis of tap-recapture data. Yield per recruit of juvenile fish and virtual population estimates presented and discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age estimates, growth curve.

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PARRACK, P.L.
1980. Trends on the abundance and age structure of Atlantic bluefin tuna. Int. Comm. Conserv. of Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 9(2):563-580.

Stock structure and abundance estimated for total Atlantic (eastern and western) and for western Atlantic catches of bluefin tuna, Thunnus thynnus. Tuna catches reported for surface fisheries during 1960-1978 compiled into length frequency data (fork length) and assigned age groups (1-39 years) estimated from von Bertalanffy growth parameters, which were determined in previously published study, Estimates of mortality rates based on tag release-recapture data and virtual population analysis (VPA) for stock abundance calculated and results discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, von Bertalanffy growth equation, stock structure.

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PARRACK, M.L., and P.L. PHARES.
1979. Aspects of growth of Atlantic bluefin tuna determined from mark-recapture data. Int. Ccnnm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 8(2):356-366.

Age and growth determined for Atlantic bluefin tuna, Thunnus thynnus, based on results of mark-recapture data collected from 1966-1977. Analysis of data from 354 mark-recaptured tuna at large from 1-97 years were used to estimate growth parameters. Von Bertalanffy, Logistic, and Richards growth parrmeters determined and estimated ages of O-30 years predicted. Comparisons made between growth models and with other published growth parameters. Weight to length conversion equations determined for May through October.

Key words: Thunnus thynnus, Atlantic bluefin tuna, mark-recapture data, von Bertalanffy growth parameters.

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PICCINETTI, C., and G.P. MANFRIN.
1970. Observazioni sulla biologia dei primi stadi grovanili del tonno (Thunnus thynnus L.). [In Ital., Enq. summ.] Boll. Pesc,a. Piscic. Idrobiol.25(2):223-247.

Examines early life history stages, geographical distribution, spawning stages and fecundity of eastern Atlantic bluefin tuna, Thunnus thynnus. Growth rates of tuna estimated to be 6-10 months old derived from weight analysis and results compared to growth rates of other previously published studies on bluefin tuna.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, juvenile growth rates.

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RIVAS, L.R.
1954. A preliminary report on the spawning of the western North Atlantic bluefin tuna (Thunnus thynnus) in the Straits of Florida. Bull. piar. Sci. Gulf Carib.4(4):31)2-322.

Season and location of spawning proposed for large, adult western Atlantic bluefin tuna, Thunnus thynnus, based on correlation of gonadal condition and occurrence of eggs and larvae in the Straits of Florida. Growth curve for 19 juvenile bluefin tuna (250-446 mm, fork length) presented and age estimated at 2-8 months. Migration, sex ratio, and fecundity discussed.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, juvenile growth.

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RIVAS, L.R.
1976. Variation in sex ratio, size differences between sexes, and change in size and age composition in western north Atlantic bluefin tuna (Thunnus thynnus). Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madm):297-300.

Compares catch data of giant western Atlantic bluefin tuna, Thunnus thynnus, caught in the Gulf of Mexico, Caribbean Sea, and the Gulf of Maine for sex ratio, size and age canposition. Estimated ages and length reported in other studies were used to assign ages to length data of Bahamas caught tuna. These estimates were compared between two time periods (1952-1955 and 1972-1973) and the age composition discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age composition.

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RIVAS, L.R.
1977a. Age composition anomalies as evidence for transoceanic migrations by intermediate age groups of the north Atlantic bluefin tuna (Thunnus thynnus). Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 6(2):270-280.

Definition of stable and unstable populations of Atlantic bluefin tuna, Thunnus thynnus, given. Medium and giant size class assigned estimated ages determined in previously published studies. Comparisons made of age compositions between eastern and western Atlantic stable and unstable populations and the results discussed. Migratory routes, season and mechanisms also discussed using supportive evidence from published tagging studies.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age composition.

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RIVAS, L.R.
1977b. Age composition, seasonal distribution of ape groups, and longevity of the western North Atlantic bluefin tuna (Thunnus thynnus). Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 6(2):287-304.

A detailed study describing the seasonal age composition of western Atlantic bluefin tuna, Thunnus thynnus, during the period 1935-19.76 based on 95,305 weight measurements collected from landings in the United States and Canada. Construction of generalized age-weight growth curve derived from previously published age and growth studies. Estimated ages of 0 to 22+ years assigned to the weight measurements ranging from 297 g. to 463 kg. Mean weight and age table presented for months May through October. Discussion of seasonal distribution by age and size, changes in the population structure during the sampling period, and life span of the population given.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, age-weight curve, age composition.

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RIVAS, L.R.
1978. Preliminary models of annual life history cycles of the north Atlantic bluefin tuna. In G.D. Sharp and A.E. Dizon (editors), The physiological ecology of tunas, p. 369-393. Academic Press, N.Y.

Annual migratory cycles described for four size categories of north Atlantic bluefin tuna, Thunnus thynnus. Length, weight, and estimated age ranges defined for each category. Geographical locations, optimum temperature and biological activities described for hi-monthly periods.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age estimates, migrations.

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ROBINS, J.P.
1963. Synopsis of biological data on bluefin tuna, Thunnus thynnus maccoyii (Castelnau) 1872. FAO Fish. Rep. 6(1):562-587

Comprehensive life history investigation conducted on southern bluefin tuna, Thunnus maccoyii, in the Pacific waters of Australia and New Zealann and growth determination based on length frequency analysis gave estimated ages of O-13 years. Length-age curve and Walford growth transformation technique employed to determine maximum length (222.5 cm, fork length). Nomenclature, distribution, migration, reproduction, population structure and variation, and exploitation discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, length frequency, length-age growth curve.

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RODRIGUEZ-RODA, J.
1964. Biologia del atun, Thunnus thynnus (L.), de la costa suda'lantica de Espana. [Ena. summ.]. Inv. Pesq. 25:33-146.

Life history investigation conducted on eastern Atlantic bluefin tuna, Thunnus thynnus, caught along the Atlantic coastal waters of Spain during 1956-1961. Age and growth determined from analysis of the anterior surface of the 4th or 5th precaudal vertebrae taken from 153 specimens resulted in estimated ages of O-13 years. Methodology for preparing and analyzing vertebra given. Table of mean length (fork length) at age and estimates of von Bertalanffy growth parameters given. Spawning season and location, maturation, tagging results and migration discussed.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, vertebra, von Bertalanffy growth parameters.

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RODRIGUEZ-RODA, J.
1971. Investigations of tuna (Thunnus thynnus) in Spain. Int. Comm. Conserv. Atl. Tunas, Rep. for the biennial peiod, 1970-71, Part II: 110-113.

Investigations conducted on the biology of the eastern Atlantic bluefin tuna, Thunnus thynnus. Age determination based on analyses of the 4th and 5th precaudal vertebrae resulted in estimated ages of 1-13 years. Length-age table and von Bertalanffy growth parameters provided: Optimum temperature requirments, spawning season, and tagging study results summarized.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, length-age table, von Bertalanffy growth parameters.

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SAKAGAWA, G.T.
1975. The purse seine fishery for bluefin tuna in the northwestern Atlantic Ocean. Mar. Fish. Rev. 37(3):1-8.

Historical account of the purse seine fishery for western Atlantic bluefin tuna, Thunnus thynnus, reviewed and fluctuation of the catch discussed. Estimated ages assigned to purse seine catch data based on previously published age and growth study indicated average age of catches decreased from 3-6 year olds in 1960 to l-3 year olds in 1973.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, purse seine catch, age composition.

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SAKAGAIJA, G.T., and A.L. COAN.
1974. A review of some aspects of the bluefin tuna (Thunnus thynnus thynnus) fisheries of the Atlantic Ocean. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid 2:259-313.

Status of Atlantic bluefin tuna, Thunnus thynnus, population examined based on analysis of catch-effort statistics of tuna catches from fisheries of various countries caught during 1960-1971. Von Bertalanffy growth parameters estimated in previously published growth studies on bluefin tuna compared and discussed. Table of length and 'weight ranges for estimated apes 1-14+ years developed from selected growth parameters. Ages assigned to size frequency data from the various fisheries of each country. The accuracy of the catch statistics, mortality estimates, recruitment estimates, and recommendations for managing the resources discussed.

Key words: Thunnus thynnus, Atlantic bluefin tuna, von Bertalanffy growth parameters, age estimates.

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SCHULTZE, D.L., and R.A. COLLINS.
1977. Age composition of California landings of bluefin tuna, Thunnus thynnus, 1963 through 1969. Cal. Fish Game Mar. Res. Tech. Rep. 38:1-44.

Estimates of ape for the California catches of Pacific bluefin tuna, Thunnus thynnus, determined based on the analysis of scales. Methodology of collecting and staining scales given. Estimated ages of 1-6 years determined for bluefin tuna ranging in size from 53 cm to 165 cm (fork length). Age composition of tuna landed during the period 1963-1969 presented. Strength of year classes also discussed.

Key words: Thunnus thynnus, eastern Pacific bluefin tuna, scale analysis, age estimates.

* *

SELLA, M.
1930. Distribution and migration of the tuna (Thunnus thynnus L.) studied by the methods of hooks and other observations. Int. Rev. d. ges. Hydrob. u. Hydrogr. 24:446-466.

Investigations conducted on life history of eastern Atlantic bluefin tuna, Thunnus thynnus. Detailed discussion of migration range and movement of bluefin tuna based on identification of fish hooks. Estimated ages of 1-14 years determined based on the examination of vertebrae from 1500 specimens. Table of fork length (cm) and weight (kg) for each estimated age given. Spawning season, feeding behavior, environmental and habitat observations mentioned.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, vertebra, ape estimates.

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SELLA, M.
1931. The tuna (Thunnus thynnus L.) of the western Atlantic -- an appeal to fishermen for the collection of hooks found in tuna fish. Int. Rev. d. ges. Hydrob. II. Hrdrogr. 25:46-67.

Description of the early fisheries and sizes of Atlantic bluefin tuna, Thunnus thynnus, observed in coastal waters of the United States and Canada. The size observations are compared to bluefin tuna caught in the eastern Atlantic Ocean and the Mediterranean Sea. Vertebra from a 29 pound bluefin tuna caught off Block Island, New York, estimated to be 2 years old based on growth rings observed. Identification of young tuna by year class (l-3 year olds) mentioned.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, vertebra, age estimates.

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SHINC-U, C.
1970. Studies relevant to distribution and migration of the southern bluefin tuna. Bull. Far Seas Fish. Res. Lab. 3:57-113.

Historical account of the surface fisheries and distribution range described for southern bluefin tuna, Thunnus maccoyii. Von Bertalanffy growth parameters presented based on analysis of length frequency data from previously published study and tag recapture data. Calculated length at each age for estimated ages 1-14 years presented and comparison between two growth equations discussed. Catch statistics, morphometric data, tagging records and oceanographic information discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, von Bertalanffy growth parameters, length frequency, tagging data, age estimates.

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SHINGU, C., and K. HISADA.
1971. Fluctuations in amount and age composition of catch of southern bluefin tuna in longline fishery, 1957-1969. [In Jap., Eng. Sum.] Bull. Far Seas Fish. Res. Lab. 5:195-218.

Historical description of the expansion of the Japanese longline fishery for southern bluefin tuna, Thunnus maccoyii, in the coastal waters of South Africa, the Indian Ocean, and southwest Pacific Ocean. Estimated ages of 2.5-14.5 years calculated from previously published sources are presented in table with average length (cm) and weight (kq) for each age. Age composition of longline catch analyzed. Fluctuation in age composition and changes in fishing effort mentioned.

Key words: Thunnus maccoyii, southern bluefin tuna, age estimates, age composition.

* * *

TIEWS, K.
1960. Bestimmung des altersaufhaues des roten thunes (Thunnus thynnus [Linnaeus]) in der Nordsee mit hilfe des allometrishen wachstums der augenhohle. Arch. Fischerewiss 11(1):12-17.

Examines the relationship between eye diameter and fork length of 1,607 giant Atlantic bluefin tuna, Thunnus thynnus, caught in the North Sea. The analysis resulted in three distinct modal groups corresponding to, 12, 13, and 14 years old based on estimated ages determined in previously published studies.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, North Sea, age estimates.

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TIEWS, K.
1963. Synopsis of biological data on bluefin tuna, Thunnus thynnus (Linnaeus) 1758 (Atlantic and Mediterranean). FAO Fish. Req. 6(1):422-481.

Review of life history investigations of Atlantic bluefin tuna, Thunnus thynnus. Age estimates indicated in previously published studies on bluefin tuna compared and discussed. Maximum estimated age of 18 years suggested for large specimens.

Key words: Thunnus thynnus, Atlantic bluefin tuna, age estimates, life history.

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VILELA, H.
1960. Estudos sobre a bioloqia dos atuns em Portugal, 1958-1960. [In Port , Eng. Summ.] Boletim da Pesca 69:11-34.

Life history investigation of eastern Atlantic bluefin tuna, Thunnus thynnus, caught along the Portugese coast from 1958-1960. Age and growth estimates determined based on the examination of the anterior cone of precaudal vertebrae from 43 specimens 115-241 cm (fork length). Estimated ages of 4-12 years determined and table of mean length for each age constructed. Sex ratio, maturity, spawning, migration, and age composition of catches also discussed.

Key words: Thunnus thynnus, eastern Atlantic bluefin tuna, vertebra, ape estimates.

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WESTMAN, J.R , and P.W. GILBERT.
1941. Notes on age determination and growth of the Atlantic bluefin tuna, Thunnus thynnus (Linnaeus). Copeia (1941)2:70-73.

Estimation of age and growth of western Atlantic bluefin tuna, Thunnus thynnus, presented based on analysis of scales from 85 specimens. Site of scale sampling and methodology of preparing and examining scales described. Estimated apes of 1-7 years determined and mean fork length (in,) at ape calculated. Estimated age of 14 years indicated for specimen weighing 345 pounds.

Key words: Thunnus thynnus, western Atlantic bluefin tuna, scale, age estimates.

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YUKINAWA, M.
1970. Age and growth of southern bluefin tuna, Thunnus maccoyii (Castelnau) by use of scales. [In Jap., Eng. Syn.Bull. Far. Seas Fish. Res. Lab. 33229-257.

Estimation of age and growth rate determined for southern bluefin tuna, Thunnus maccoyii, caught during 1963-1968 in coastal waters of Australia based on the analyses of scales, length frequency, and tagging data. Scales from 1,025 specimens ranging in length 31-190 cm (fork length) resulted in estimated ages l-9 years and compared with results from length frequency analysis and tag-recovery data. Von Bertalanffy growth parameters calculated and growth curve compared to previously published growth study based on length frequency. Regression analysis of scale radius to fish length presented and results of back calculated fish length to age discussed.

Key words: Thunnus maccoyii, southern bluefin tuna, age estimates, scales, von Bertalanffy parameters.

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YUKINAWA, M., and Y. YABUTA.
1967. Age and growth of the bluefin tuna, Thunnus thynnus (Linnaeus), in the north Pacific Ocean. [In Jap., Eng. Abs.]Nankai Req. Fish. Res. Lab. 25:1-19.

Ape and growth estimated for Pacific bluefin tuna, Thunnus thynnus, caught in coastal waters of Japan during 1953-1963 based on scale analysis. Methodology for collecting, preparing, and examining scales given. Relationship of scale radias to fish length analyzed and estimated ages of 1-8 years determined for 164 specimens 48-221 cm (fork length). Von Bertalanffy growth parameters derived and length-age table given. Growth model determined from scale analysis compared to tagging study results and to growth models determined in other studies on Pacific and Atlantic bluefin tuna. Time of year of ring formation and spawning season discussed.

Key words: Thunnus thynnus, western Pacific bluefin tuna, scales, von Bertalanffy parameters, age estimates.

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Butler 1974
Butler et al. 1977
Caddy and Butler 1974
Compeán-Jimenez and Bard 1980
Compeán-Jimenez and Bard (In press)
Farber and Lee 1981
Hamre 1958
Hunt 1978
Hurley and Iles (In press)
Hurley et al. 1981
Koski 1967
Lee et al. (In press)
Lucas 1974
Mather and Schuck 1960
Nichy and Berry 1976
Rodriguez-Roda 1964
Schultze and Collins 1977
Westman and Gilbert 1941
Yukinawa and Yabuta 1967

VON BERTALANFFY PARAMETERS
Bard et al. 1978
Bayliff 1980
Bayliff and Calkins 1979
Butler 1971
Butler et al. 1977
Caddy 1974
Coan 1976
Compeán-Jimenez and Bard 1980
Compeán-Jimenez and Bard (In press)
Farber and Lee 1981
Farrugio 1978
Hunt 1978
Hurley and Iles 1982a
Hurley and Iles (In press)
Hurley et al. 1981
Koski 1967
Lucas 1974
Majkowski and Hampton (In press)
Murphy 1977
Murphy and Majkowski 1981
Olson 1980
Parrack and Phares 1979
Robins 1963
Rodriguez-Roda 1964
Rodriguez-Roda 1971
Sakagawa and Coan 1974
Shingu 1970
Yukinawa 1970
Yukinawa and Yabuta 1967

GROWTH CURVES
Butler 1974
Butler et al. 1977
Compeán-Jimenez and Bard 1980
Compeán-Jimenez and Bard (In press)
Farber and Lee 1981
Farrugio 1978
Farrugio 1980
Hamre 1958
Hayashi 1957
Kimura 1932
Lucas 1974
Mather and Schuck 1960
Murphy and Majkowski 1981
Parrack 1979
Parrack and Phares 1979
Pincinetti and Manfrin 1970
Rivas 1954
Robins 1963
Rodriguez-Roda 1964
Yukinawa 1970
Yukinawa and Yabuta 1967

LENGTH/WEIGHT/AGE TABLES
Aikawa and Kato 1938
Bard et al. 1978
Bell 1963
Butler 1974
Coan 1976
Compeán-Jimenez and Bard 1980
Compeán-Jimenez and Bard (In press)
Farrugio 1977
Farrugio 1978
Farrugio 1979b
Farrugio 1980
Hamre 1958
Hurley and Iles (In press)
Le Gall 1954
Mather 1974
Mather and Jones 1972
Mather and Schuck 1960
Olson 1980
Rivas 1977b
Rivas 1978
Rodriguez-Roda 1964
Rodriguez-Roda 1971
Sakagawa and Coan 1974
Sella 1930
Shingu 1970
Shingu and Hisada 1971
Vilela 1960
Westman and Gilbert 1941
Yukinawa and Yabuta 1967

AGE COMPOSITION
Bard et al. 1978
Caddy and Butler 1976
Farrugio 1977
Farrugio 1978
Farrugio 1979a
Hamre 1958
Hurley and Iles 1982b
Isaacson 1964
Majkowski and Hampton (In press)
Mather and Jones 1972
Parrack 1980
Rivas 1976
Rivas 1977a
Rivas 1977b
Sakagawa 1975
Sakagawa and Coan 1974
Schultze and Collins 1977
Shingu and Hisada 1971
Vilela 1960